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Moving from Subjective to Objective Evaluation of Pavement Performance

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Moving from Subjective to Objective Evaluation of Pavement Performance

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Abstract:	This paper discusses measures of pavement performance as used by pavement engineers and the use of such measures in pavement management processes. The attributes and benefits of an objective pavement performance evaluation scheme developed for the Ontario Ministry of Transportation and Communications are described. The scheme forms a Pavement Condition Index by combining mechanically-measured roughness data and data on 15 pavement distress manifestations, such as course aggregate loss and ravelling, rutting, and centreline cracking. The benefits of the systems include: a) it increases the authoritativeness and acceptability of pavement condition rating; b) it makes distress data available for the timely selection of pavement preservation treatments; and c) it provides feedback data for improved pavement design and evaluation procedures.
Key words	pavement performance, course aggregate, ravelling, rutting, centreline cracking
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INTRODUCTION

Evaluation and rating of pavement performance are fundamental requirements for rational decisions in pavement management. However, there are many measures of pavement performance (including roughness, observable pavement distresses, and pavement structural integrity or capacity), and the pavement management engineer must decide which pavement performance measure, or a combination of measures, would best reflect pavement management objectives and would be appropriate for local conditions. One of the purposes of this report is to help the pavement management engineer in the selection of pavement performance measures.

Traditionally, pavement performance has been defined as an indicator of how well the pavement serves the travelling public and pavement performance has primarily been measured in terms of roughness. Pavement roughness has long been recognized as a measure related to road user comfort, cost and safety. For example, the AASHO Road Test of the early 1960s attributed about 95% of pavement performance to the influence of roughness [1] and the remaining 5% to the influence of other factors such as rutting and cracking. The pavement performance measured in terms of roughness is referred to as functional pavement performance.

With the growing emphasis on pavement preservation of mature highway networks in an environment of fiscal constraint, it is desirable to measure pavement performance also in terms of pavement distresses which may cause an accelerated loss of pavement serviceability and/or distresses which may trigger pavement preservation actions. The knowledge of pavement roughness alone is often insufficient for timely selection of specific pavement preservation actions. For example, routing and sealing of transverse cracks may be required to protect the pavement structure even though the presence of cracks has not yet influenced pavement roughness. Moreover, routing and sealing of transverse cracks which are already stepped, and thus influencing pavement roughness, usually comes too late to be effective in extending pavement life.

This emphasis on pavement preservation from the owner's viewpoint must be reflected in the way pavement performance is measured. Pavement performance based on evaluation of pavement distress is referred to as structural pavement performance. Characteristically, structural pavement performance is used for evaluating highway networks with structurally adequate pavements [2].

The two pavement performance measures (functional performance and structural performance) do not conflict as much as they may appear to because pavement distresses and roughness are interrelated. Moreover, pavement roughness and individual

pavement distresses can be combined to yield an indicator of overall pavement serviceability.

PAVEMENT RATING IN ONTARIO

The Ontario Ministry of Transportation and Communications (MTC) has been systematically rating pavement performance since the mid-1960s using a subjectively assigned Pavement Condition Rating (PCR) [3]. The PCR was originally developed to facilitate planning of pavement rehabilitation actions, and while this rating has remained unchanged, its use has been greatly expanded. For example, the PCR has been used as a key pavement performance measure for pavement design purposes [4].

The PCR is based on a subjective comparison of pavement condition observations against a set of model descriptions. The models trace the deterioration of serviceability by varying attributes of riding quality and distortion, cracking and alligatoring, and rutting and dishing from, say, excellent to very poor. As well as rating numbers assigned to each model, suggestions for type and timing of rehabilitation are attached. For example, the model descriptions for a "pavement in fairly good condition with slight cracking, slight or very slight dishing and a few areas of slight alligatoring, rideability being fairly good with intermittent rough and uneven sections," would have the PCR fixed between 65 and 75, and resurfacing would be recommended within 3 to 5 years.

In the 1970s, it was realized that pavement performance evaluation should be done using a more objective and consistent measure of pavement performance. This led to the development and recent introduction of Pavement Condition Index (PCI) [5]. The PCI is measured on a scale of 0 to 100 and comprises two different physical parameters:

a) The riding quality of the pavement surface as perceived by the travelling public. This is based on mechanical measurements using a response-type road roughness meter, PURD, [6] and is expressed as Ride Comfort Rating (RCR) on a scale from 0 to 10.

b) The extent and severity of pavement distress manifestations expressed as Distress Manifestation Index (DMI). Pavement distress manifestations are defined as visible consequences of various pavement distress mechanisms which usually lead to a reduction in pavement performance. The DMI summarizes the contribution of up to 15 distresses, listed in Table 1, taking into account their type, severity and density.

The two PCI components, RCR and DMI, are combined using the following equation [5]:

$$PCI = 100\ (0.1\ RCR)^{1/2}\ \frac{205 - DMI}{205} \cdot c \qquad (1)$$

where:

PCI = Pavement Condition Index; PCI ≤ 100
RCR = Riding Comfort Rating based on PURD
205 = Probable maximum value of DMI

$$DMI = \text{Distress Manifestation Index} = \sum_{i=1}^{15} w_i\ (s_i + d_i) \qquad (2)$$

w_i = weighting value representing the relative weight of each distress manifestation on a scale from 0 to 3. The weighting values are listed in Table 2.

s_i = severity of distress manifestations expressed on a scale from 0 to 4. Severity of distresses is described in Table 1 and its s_i values are given in Table 2.

d_i = density of distress occurrence expressed on a scale from 0 to 4. Density of distresses is described Table 3 and its d_i values are given in Table 2.

c = calibration constant to ensure that PCI is, on the average, numerically equal to the PCR.

If applicable, the RCR and DMI measures can be also considered separately as descriptors of functional and structural pavement performance, respectively.

The evaluation of pavement distress manifestations is scheduled to be done every two years (compared to every three years for PCR). Distresses are rated to reflect average condition on the total length of the pavement section rated. The sections are selected so as to exhibit a uniform pavement performance. They range in length from about 1 to 25 km.

The severity and density of pavement distresses are rated using a well-documented methodology [3] which uses detailed guidelines and photographs to achieve uniformity in interpretation and reporting. This enables the observer to quantify each distress on severity and density scales ranging from 0 to 4. Distress manifestation data, as well as roughness and other data, are stored for all survey years in a pavement management information data bank.

REPORT OBJECTIVES

The recent change and conversion from the subjective PCR to the more objective PCI measure, provided an opportunity to study and quantify a number of issues connected with pavement performance evaluation. The results of some of these studies are summarized in this report under the following two topics.

a) Benefits of using objective pavement performance measures. The question being asked was: what sorts of benefits in terms of consistency and reliability can be expected from using objective pavement performance measures rather than subjective measures?

b) Occurrence of pavement distresses with the emphasis on the occurrence of distresses reaching critical or failure levels of severity and density. The main questions asked were:
   - What are the principal failure modes of Ontario pavements? and
   - What are their implications for pavement design and evaluation?

OBJECTIVE AND SUBJECTIVE EVALUATION OF PAVEMENT PERFORMANCE

As mentioned, the Pavement Performance Rating (PCR) is based on subjective evaluation of overall pavement performance. Nevertheless, to ensure reproducibility, subjective measures such as PCR must be also related to actual observable pavement characteristics, namely, various distress manifestations and roughness. The degree of relationship between these characteristics and the PCR has been quantified to assess the benefits of using objective pavement measurements in terms of reproducibility and reliability.

Pavement performance data for three MTC Districts (Stratford, Kingston, and Huntsville) with known measured roughness were used in this study. The three Districts provided a province-wide representative sample of pavement conditions associated with a variety of pavement structures and traffic and environmental exposures. All asphalt concrete pavements on the King's Highways in the three districts were included in the study. The sample contained about 300 sections on 3950 2-lane km. Each section was characterized by:

- the PCR,
- 15 distresses with values calculated as a sum of their severity and density ratings (value of $s_i + d_i$ defined in Equation 2),
- Ride Comfort Rating (RCR) based on PURD roughness measurements, and
- type and density of occurrence of various maintenance treatments such as machine patching and spray patching.

The evaluation technique was based on multiple regression analysis despite some limitations caused by multicollinearity in the independent variables [9]. For example, under these circumstances, the regression may not provide reliable partial correlation coefficients. However, the study results were expressed in terms of the total variance explained by the regression model (R-square multiplied by 100) which is not overly sensitive to the problem of multicollinearity.

Several multiple regression models predicting the PCR as a function of observed pavement characteristics were constructed and evaluated. The models were based on more than 300 observations. The best multiple regression model relating PCR with observed pavement characteristics (15 distresses, RCR, occurrence of maintenance treatments) explained only 71% of the total PCR variance (Table 3). A further 10% of the variance could be explained by including age and traffic volumes as dependent variables, even though these two variables should not be considered when determining the PCR. The rest of the PCR variance (19%) could not be attributed to any of the variables selected. In other words, it appears that, on average, a substantial portion of the PCR value is assigned arbitrarily, or is assigned in an unknown manner. The pavement distresses alone explained about 64% of the PCR variance while the RCR explained only 32% (Table 3).

On the other hand, the objectively established Pavement Condition Index (PCI), defined by Equation 1, is entirely determined by measured or observed pavement performance characteristics. The replacement of PCR with PCI should thus improve the reproducibility and reliability of pavement performance rating and enhance its authoritativeness and acceptability.

Using the same data set, attempts were also made to construct a multiple prediction model which would predict RCR (based on PURD) as a function of the 15 distresses. The results were unsuccessful judging by the multiple correlation coefficient (R-square) of only 0.30 obtained for this model. This indicates that pavement roughness, unlike the PCR, cannot be reliably predicted from distresses alone and that an overall rating of pavement performance requires both the roughness measurement and the evaluation of individual pavement distresses.

OCCURRENCE OF PAVEMENT DISTRESSES

The field observation and recording of pavement distress manifestations can serve three basic purposes. Obviously, one purpose is pavement evaluation and ranking as illustrated by the use of the Distress Manifestation Index. A second purpose is timely selection of specific pavement preservation

treatments such as routing and sealing of cracks. Thirdly, the process contributes to fundamental understanding of pavement performance and thus enables rational pavement design. Some aspects of the third application are discussed in the following.

For a rational approach to pavement design, it is important to know the predominant pavement distress type so that appropriate design precautions can be taken. For example, it is often claimed that the most important distress of primary flexible pavements in the United States is fatigue cracking [7]. A design response for such distress would probably be to increase the strength of the pavement structure. If, on the other hand, the predominant distresses were ravelling or low-temperature cracking, a design response would probably address asphalt concrete mix design.

Knowledge of the incidence of different distresses is also useful in the pavement evaluation process. It enables one to place proper emphasis on the evaluation and monitoring of the predominant or critical distress modes.

A statistical study evaluating the occurrence of pavement distress manifestations has been conducted for two selected MTC regions, Southwestern Region and Northern Region, using the most recent data stored in the pavement management information data bank. The regions represent two different, yet typical, Ontario environments. The location of the two regions, together with their iso-freezing index lines [8], is illustrated in Figure 1. The highway networks of the two regions are roughly equal in size and, together, they comprise about 7200 centreline kilometres, about 45% of the provincial highway network.

All asphalt concrete pavement sections in the two regions, for which data were available, were included in the study. Altogether, 474 sections of 9.4 km average length were evaluated in Southwestern Region and 286 sections of 14.7 km average length were evaluated in Northern Region. The sections encompassed a variety of pavement structures and subgrades. Annual Average Daily Traffic in Southwestern Region ranged from about 500 to 42 000 with an average of 7400; and in Northern Region, it ranged from about 500 to 20 000 with an average of about 3200.

The occurrence of the 15 distresses which form the Distress Manifestation Index (DMI) is compared in Figure 2. Distress manifestations shown in Figure 2 are for all 15 distresses which have been observed in the field regardless of their severity or density. The frequency of occurrence shown in Figure 2 represents the percentage of sections with a given distress. For example, about 92% of all sections in Southwestern Region exhibited some form of single and multiple

transverse cracking. Other distresses with a high level of occurrence (above 80% of all sections) in Southwestern Region included coarse aggregate loss and ravelling, and single and multiple centreline cracking. In Northern Region, the most frequent distresses were rutting, distortion, single and multiple transverse cracking, and longitudinal meander and midlane cracking. In both regions the occurrence of transverse alligator cracking was noticeably slight.

The mere presence of a distress does not mean that the distress results in a pavement failure or even a significant loss of pavement performance. For example, very slight wheel track rutting, characterized by a depth of less than 6 mm (Table 1), which exists throughout the pavement section, does not mean that a pavement failure occurred. In order to identify distresses which significantly affect pavement performance and thus have pavement design and evaluation implications, analysis of distresses reaching critical levels of severity and density was undertaken.

A distress was considered to reach a critical level (i.e., affecting performance) if its severity was at least moderate, as defined in Table 1, while concurrently, density was at least frequent (as defined in Table 2). An exception to this rule was made for all four types of alligator cracking distresses. These were considered to reach critical levels if their severity was slight or higher (rather than moderate) and their density frequent or higher (as before).

These severity levels were selected as one characteristic constituting a distress reaching a critical level or "critical distress" because at these distress levels, the pavement structure can be considered to have reached a turning point in the failure mode due to the given distress. For example, moderate wheel track rutting is characterized by rut depth of 12 to 19 mm with some cracking in the wheel path, and moderate single and multiple transverse cracking is characterized by crack width of 12 to 19 mm with slight stepping and/or formation of multiple cracks (Table 1).

The second characteristic constituting a critical distress was frequent density of occurrence, defined in Table 2 as occurrence on at least 20% of the pavement section. This was used to eliminate or reduce the influence of local (nonuniform) structural and environmental conditions.

The frequencies of distresses reaching critical levels are compared for the two regions in Figure 3. There are several considerable differences between the regions. For example, longitudinal meander and midlane cracking reached critical levels on about 48% of sections in Northern Region and only on about 7% of sections in Southwestern Region. This may indicate that pavements in Northern Region are more

susceptible to differential heave/settlements and frost action and that greater design precautions should be taken to counteract this type of distress in Northern Region.

Before discussing the incidence of critical distresses, another important factor, the age of pavement, must be taken into account. In other words, it is not sufficient to know which distresses reach critical levels most frequently, it is also necessary to know at which pavement age these distresses occur. It is expected that when a pavement reaches its design lifespan, some of its distresses would reach or exceed their critical levels. However, the distresses which reach critical levels well before the expected pavement life is attained are the ones which seriously contribute to premature pavement failure.

The incidence of 12 selected distresses reaching critical levels (i.e., critical distresses) is presented in Figures 4a and 4b, which show cumulative frequency graphs plotted against pavement age. The distribution of pavement age in the two regions is shown in Figure 5. The average pavement age was 9.4 years in Southwestern Region and 8.7 years in Northern Region.

Coarse aggregate loss and ravelling seems to be an important distress reaching critical levels on about 24% of all sections in Southwestern Region and on about 12% of all sections in Northern Region (Figure 4a, upper left-hand corner). This distress is atypical because it is caused by two different causes. In Ontario, coarse aggregate loss is usually caused by the poor quality of aggregate particles which fracture or disintegrate; ravelling is usually caused by faulty hot mix placement (segregation, poor compaction). Thus, it is difficult to interpret the occurrence of this distress in terms of its implications for improving asphalt concrete mixes. Judged by experience, the high occurrence of the distress in Southwestern Region is probably due to coarse aggregate loss rather than ravelling.

Flushing distress reaching critical levels occurred only on two sections in Southwestern Region and on only about 5% of sections in Northern Region. All sections were 4 years old or older. It appears that all 51 recently paved sections in Northern Region which are less than 4 years old (Figure 5) are without flushing problems. Rippling and shoving exhibited trends similar to flushing.

Wheel track rutting (Figure 4a) is an important distress in Northern Region with about 20% of all sections affected. Since average traffic volumes in Northern Region are less than half of those in Southwestern Region, the difference in rutting frequency may be attributed to inadequate pavement structures in Northern Region. It should also be noted that

the incidence of critical rutting levels in Southwestern Region increases more-or-less linearly with age. At the age of 15 years, about 6% of the sections reached critical rutting levels.

Distortion (any deviation of the pavement surface from its original shape other than that described by rippling, shoving, and rutting) was also more frequent in Northern Region, reaching critical levels on about 9% of the sections. The higher occurrence of distortion in Northern Region is expected since distortion is usually caused by differential heave/settlement due to frost action and nonuniform subgrade support. The occurrence of distortion seems to stabilize after the pavement reaches 15 years of age.

The incidence of single and multiple longitudinal wheel track cracking closely resembles that of rutting. The presence of these two distresses is highly correlated [9] and may be due to similar causes.

The occurrence of single and multiple centreline cracking (Figure 4b) is remarkably similar in both regions. After 20 years, critical levels of this distress were reached on about 20% of all sections in both regions. This coincidence lends support to the usual attribution of this distress, namely poor longitudinal joint construction, since construction techniques are quite similar in both regions.

Alligator centreline cracking was selected for inclusion in Figure 4b to represent the occurrence of all four types of alligator cracking (centreline, longitudinal wheel track, pavement edge, and alligator). All alligator cracking distresses occurred relatively infrequently, particularly in Southwestern Region. The highest incidence of any type of alligator cracking was observed in Northern Region for alligator longitudinal wheel track cracking. This occurred on about 7% of all sections.

Single and multiple pavement edge cracking is defined as cracking parallel to and within 30 cm of the pavement edge. It reached critical levels on about 20% of sections in Northern Region and on about 10% of sections in Southwestern Region.

Single and multiple transverse cracking appears to be a predominant distress mode in both regions, reaching critical levels on about 40% of all sections in Northern Region and on about 25% of sections in Southwestern Region. This distress is usually attributed to low-temperature shrinkage of asphalt concrete mix and, in the case of overlays, also to reflection cracking.

Single and multiple longitudinal and meander and midlane cracking occurs mostly in Northern Region. This distress is usually attributed to frost action and to mixes which have lost cohesion due to stripping, and to improperly adjusted paving screeds. In general, mixes in Northern Region tend to have a coarser aggregate gradation than mixes in Southwestern Region. These mixes are more susceptible to segregation at the location where two transverse screws, which distribute hot mix inside a typical paver, meet; i.e., the midlane.

Random cracking which runs randomly across and along the pavement surface does not seem to be a significant distress in either region.

In summary, there are many possibilities how to analyse, evaluate and interpret pavement distresses. Also, many distresses are correlated and often several distresses with critical levels of severity and density can occur on the same section as shown in Figure 6. Nevertheless, to illustrate some of the benefits of objectively measured pavement distresses in terms of pavement design implications and as a feedback for improved pavement evaluation, the following observations are offered:

a) Pavement Design Implications

- The predominant pavement failure modes in Southwestern Region appear to be environment-associated centreline and transverse cracking and coarse aggregate loss and ravelling. The traditional design response would call for the use of asphalt mixes less susceptible to temperature, increased asphalt content, improved construction practices and the use of materials less prone to frost action.

- The predominant pavement failure modes in the Northern Region are associated with environmental causes (resulting in transverse cracking and meander cracking) and with insufficient pavement structural strength (resulting in rutting, and pavement edge and wheel track cracking). Thus, the traditional design response would call for increased structural strength and improved protection against frost action, the use of asphalt cements less susceptible to temperature, and improved stripping resistance.

b) Improved Pavement Evaluation

- Because coarse aggregate loss and ravelling distress reaches critical levels quite frequently, and has two distinct causes, it may be advantageous to evaluate and record ravelling separately from the coarse aggregate loss.

- Since all four types of alligator cracking occur quite infrequently at any level of severity or density (Figure 2), it may be possible to combine some types of alligator cracking (for example, the centreline and longitudinal wheel track types).

- Random cracking, which seldom reaches critical levels, may be combined with longitudinal meander and midlane cracking.

SUMMARY AND CONCLUSIONS

1. Systematic evaluation of pavement distresses provides significant benefits for pavement management:
   a) It provides a key component for an overall measure of pavement performance.
   b) It facilitates a timely selection of pavement preservation treatments.
   c) It enables one to statistically identify the most important pavement failure modes.
   d) It provides a flexible evaluation scheme which can be tailored to respond to and reflect local conditions.

2. Up to 30% of the variance in the subjectively determined Pavement Condition Rating (PCR) could not be explained by actual observed pavement performance characteristics such as pavement distresses and roughness. However, the recently introduced Pavement Condition Index (PCI) depends entirely on measured or observable pavement characteristics. The use of PCI increases the authoritativeness, consistency, and acceptability of pavement condition rating for pavement management purposes.

3. Based on a statistical evaluation of pavement distresses, the predominant pavement modes in Southwestern Region appear to be environment-associated cracking and coarse aggregate loss and ravelling. The predominant failure modes in Northern Region are environment-associated cracking and rutting, pavement edge cracking and wheel track cracking. Such analyses of performance data can yield valuable indications about actions which need to be taken to improve future pavement performance. It is intended that similar analyses be carried out in other regions.

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Table 1/Guide for Describing Severity of Pavement Distresses

Severity of Distress	1 Coarse Aggregate Loss and Ravelling	2 Flushing	3 Rippling and Shoving	4 Wheel Track Rutting	5 Distortion	Single & Multiple Cracks		Alligator Cracking	10-11 Pavement Edge Cracking
						6. Longitudinal Wheel Track 8. Centreline 14. Meander and Midlane 15. Random	12. Transverse	7. Longitudinal Wheel Track 9. Centreline 13. Transverse	
1 Very Slight	Barely Noticeable	Very faint colouring	Barely noticeable	Barely noticeable (< 6 mm)	Noticeable swaying motion	Crack width < 2 mm Hairline	Crack width < 2 mm Full and partial cracks	Alligator pattern forming Depression < 12 mm	Single longitudinal or single wave-formation
2 Slight	Noticeable	Colouring visible	Noticeable	6 to 12 mm	Good control of car still present	2 to 12 mm width Single cracks	2 to 12 mm width Single full-width cracks	Alligator pattern established with corners fracturing Depression > 12 mm	Multiple parallel longitudinal or wave-formation less than 0.5 m from pavement edge
3 Moderate	Pock-marks well-spaced, open texture	Distinctive appearance with free asphalt	Rough ride Washboard appearance	12 to 19 mm Multiple cracks may be starting	Fair control of car	12 to 19 mm width Multiple cracks starting	12 to 19 mm width Single full cracks with slight cupping or lipping or multiple cracks starting	Alligator pattern established with spalling of blocks Depression > 19 mm	Progressive multiple cracks extend over 0.5 m but less than 1 m from edge. Crack begins to braid.
4 Severe	Pock marks closely-spaced, disintegration, small pot holes	Free asphalt on surface, has wet look	Very rough ride Pronounced washboard appearance	19 to 25 mm May include multiple longi-tudinal cracks	Poor control of car	19 to 25 mm width Multiple cracks, spalling begins to develop	19 to 25 mm width Single full cracks with moderate cupping or lipping, or multiple cracks	Blocks begin to lift, patching required. Depression > 25 mm	Progressive multiple cracks extend over 1.0 m but less than 1.5 m from edge. Begins to alligator.
5 Very Severe	Disintegrated with large pot holes	Wet look with tire noise like wet pavement surface	May cause loss of control of vehicle	Rutting>25mm May include multiple longi-tudinal cracks	Continuous distortion, may be dangerous at speeds > 60 km/h	Width > 25 mm Multiple cracks with spalling developed. May begin to alligator.	Width > 25 mm Severe cupping or lipping, multiple cracks with spalling. May begin to alligator.	Complete disintegration of affected area, pot holes from missing block. Depression > 50 mm	Progressive multiple cracks extend over 1.5 m from edge. Outermost area near edge is alligatored.

Note: - Crack width should be determined during the period from May to October.
Do not report routed and sealed cracks, these will be reported as Maintenance Treatment.

Table 2/ Assessment of Distress Manifestations

Weighting values, w_i

	DESCRIPTION OF DISTRESS	WEIGHTING VALUE w_i
SURFACE DEFECTS	1/ Coarse Aggregate Loss and Ravelling	3.0
	2/ Flushing	0.5
	3/ Rippling and Shoving	1.0
SURFACE DEFORMATION	4/ Wheel Track Rutting	3.0
	5/ Distortion	3.0
CRACKING	6/ Longitudinal Wheel Track - Single - Multiple	1.0
	7/ Longitudinal Wheel Track - Alligator	3.0
	8/ Centreline - Single - Multiple	0.5
	9/ Centreline - Alligator	2.0
	10/ Pavement Edge - Single - Multiple	0.5
	11/ Pavement Edge - Alligator	1.5
	12/ Transverse - Half - Full- Mult.	1.0
	13/ Transverse - Alligator	3.0
	14/ Longitudinal Meander and Midlane	1.0
	15/ Random	0.5

Severity of Distress, s_i

Description	s_i
Very slight	0.5
Slight	1
Moderate	2
Severe	3
Very Severe	4

Density of Distress, d_i

Description	Percentage	d_i
Few	<10	0.5
Intermittent	10-20	1
Frequent	20-50	2
Extensive	50-80	3
Throughout	>80	4

Table 3/ Guide for Describing Density of Pavement Distresses

Class or Code	Description	For all Distresses Except Transverse Cracking*	For Transverse Cracking Only
1	Few	< 10%	Cracks (full and/or half cracks) are more than about: 40 m apart
2	Intermittent	10 - 20%	No set pattern. Cracks (full and/or half) are about: 30 to 40 m apart
3	Frequent	20 - 50%	A set pattern. Cracks (full and/or half) are about: 20 to 30 m apart
4	Extensive	50 - 80%	Rather regular pattern. Cracks (full and/or half) are about: 10 to 20 m apart
5	Throughout	80 - 100%	Regular pattern. Cracks (full and/or half) are less than about: 10 m apart

* *Based on percent of surface area within the PMS section affected by distress*

Table 4/ Descriptive Capabilities of Pavement Characteristics

Independent Variables	Percentage of PCR Variance	
	Explained by Independent Variables	Unexplained
Riding Comfort Rating (RCR) only	32	68
15 Distress Manifestations	64	36
15 Distress Manifestations + RCR	71	29
15 Distress Manif. + RCR + Age + Traffic Volume	81	19

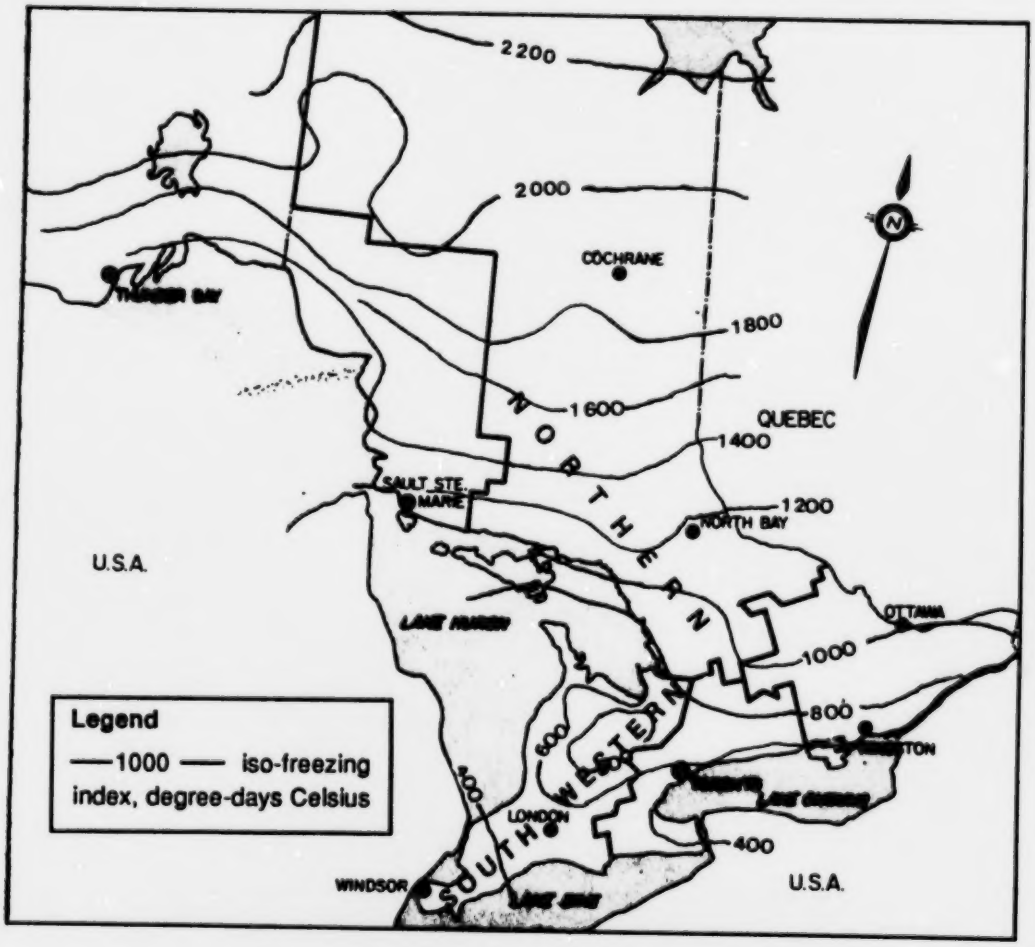

Figure 1/ Location of Southwestern and Northern Regions

Figure 3/ Occurrence of Distress Manifestations, Critical Levels

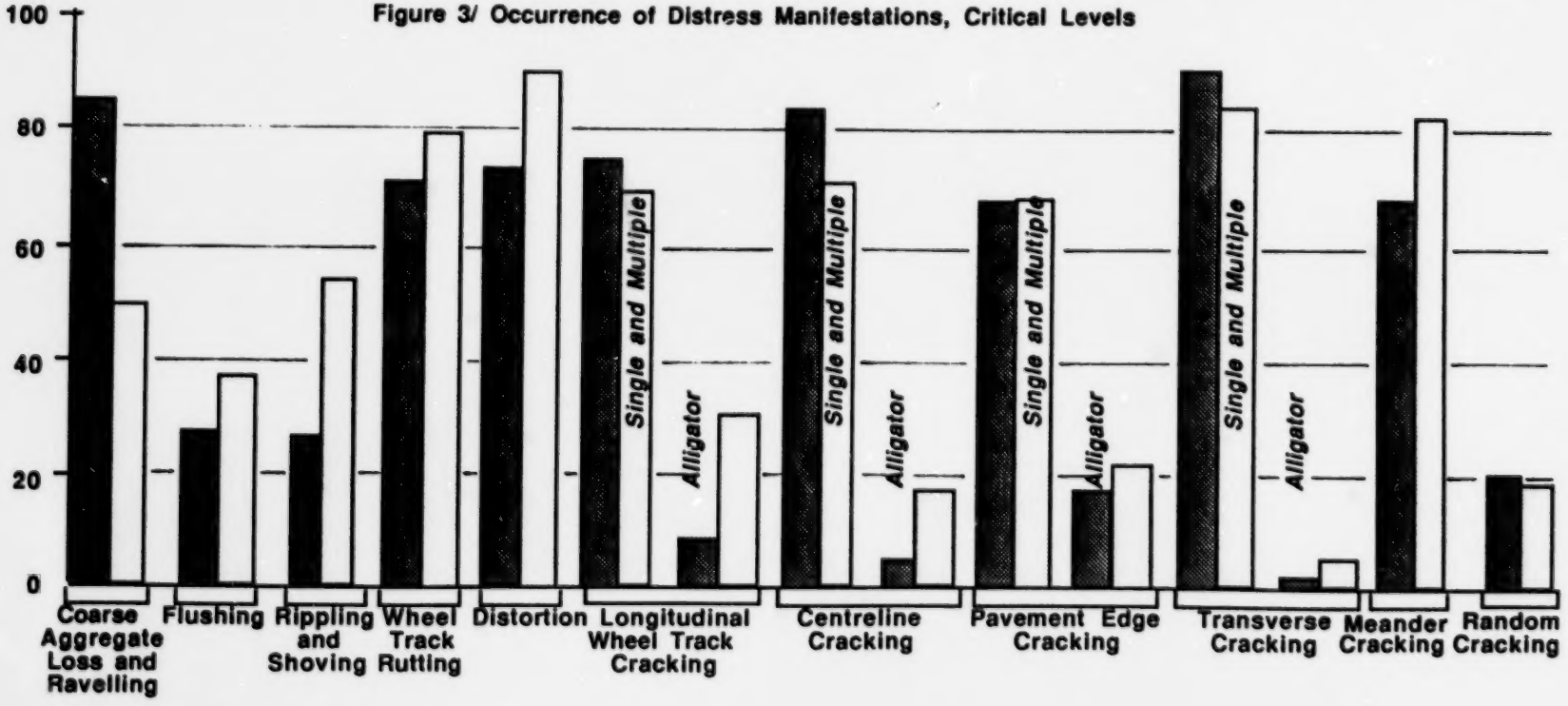

Figure 2/ Occurrence of Distress Manifestations, All Levels of Severity and Density

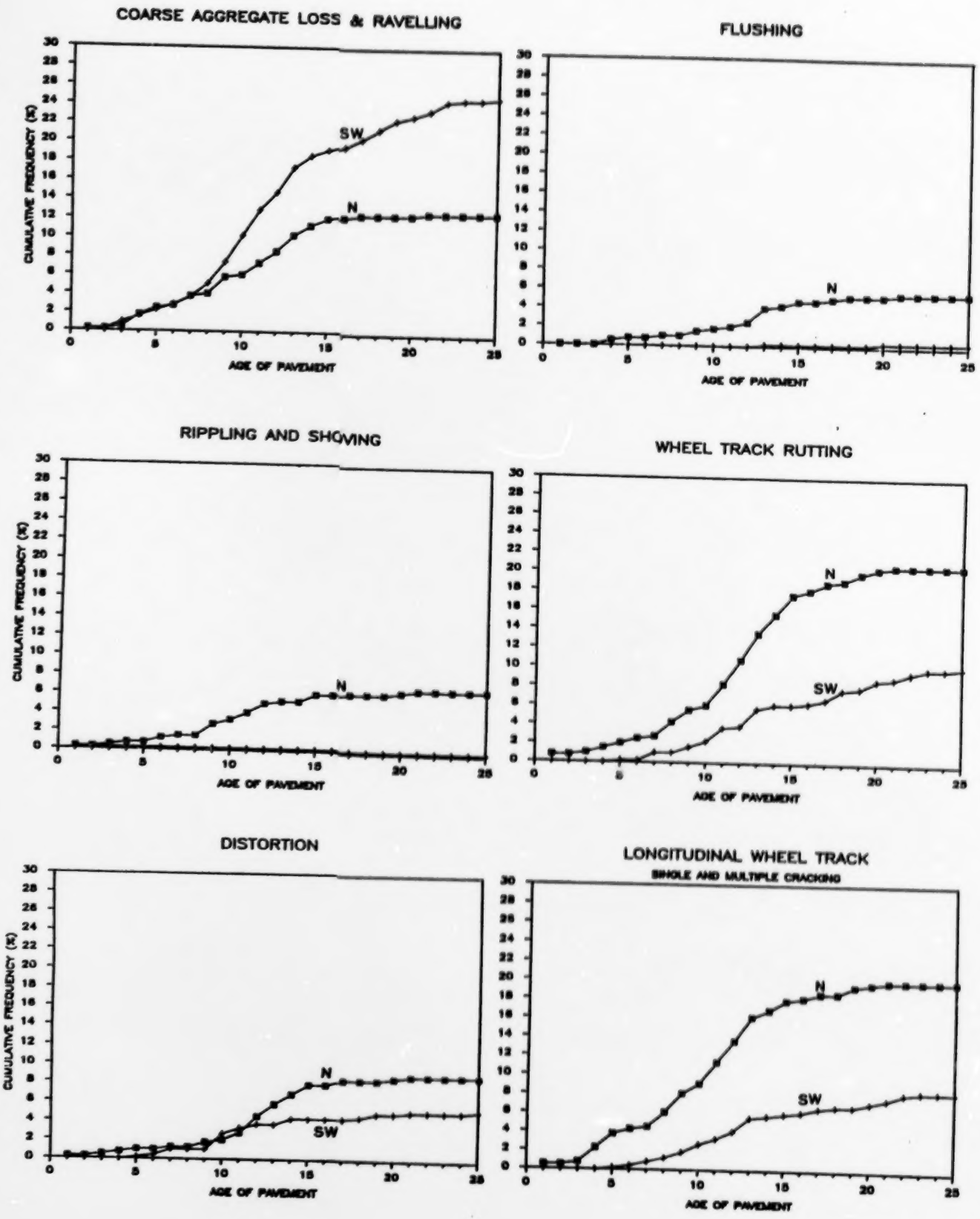

Figure 4a/ Occurrence of Critical Distresses as a Function of Pavement Age

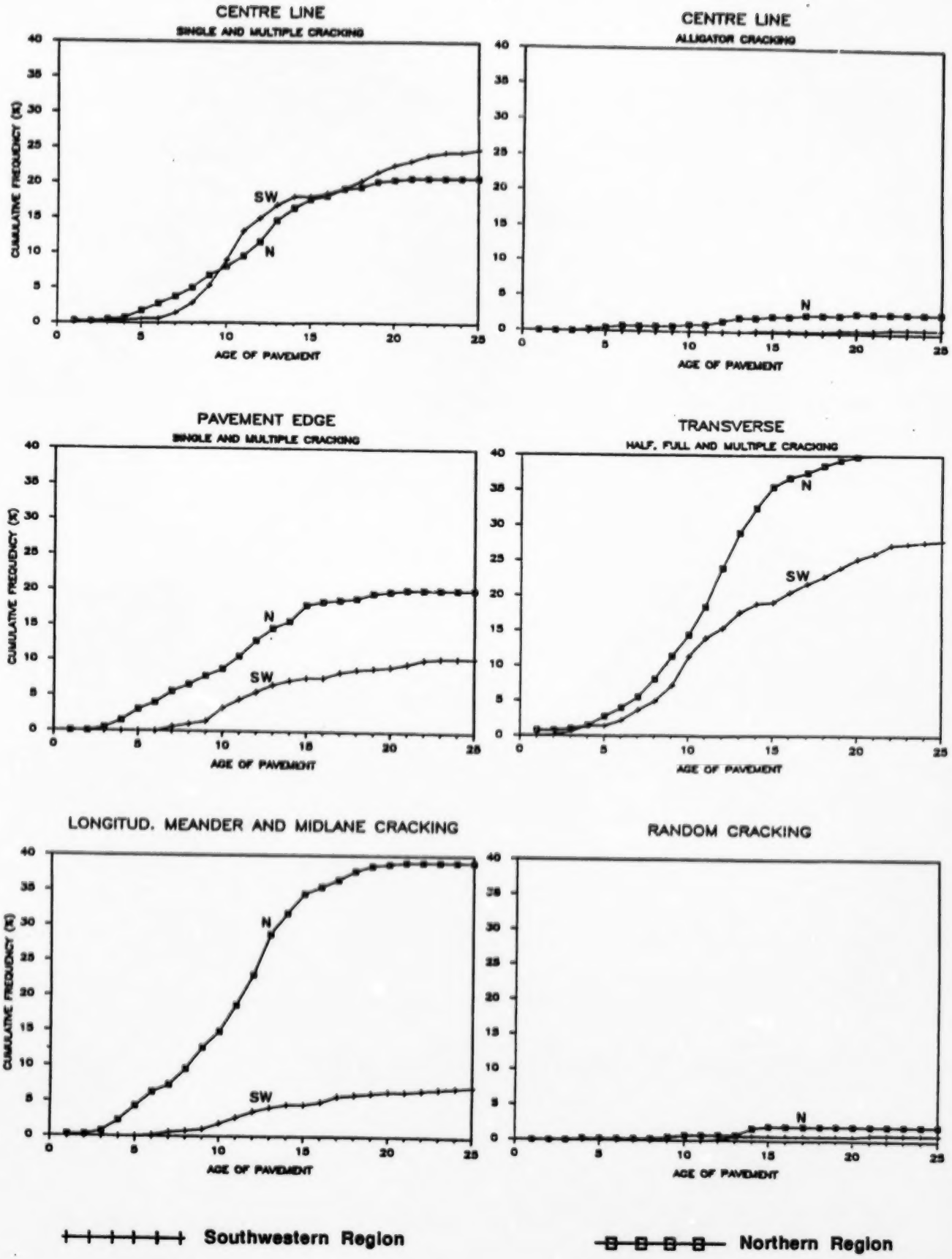

Figure 4b/ Occurrence of Critical Distresses as a Function of Pavement Age

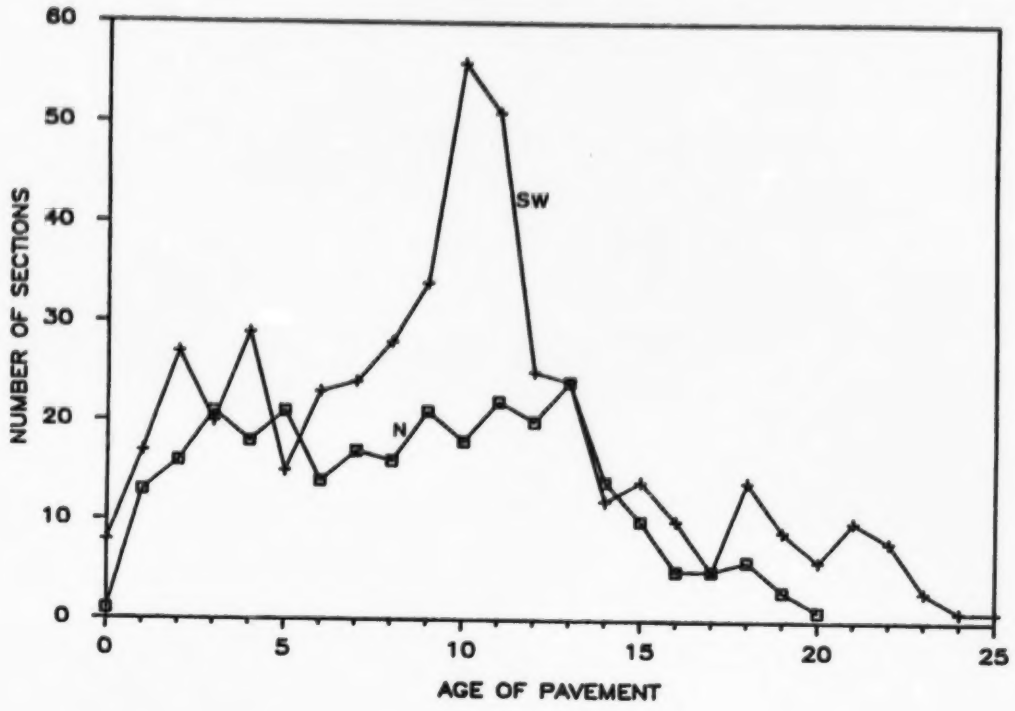

Figure 5/ Pavement Age Distribution

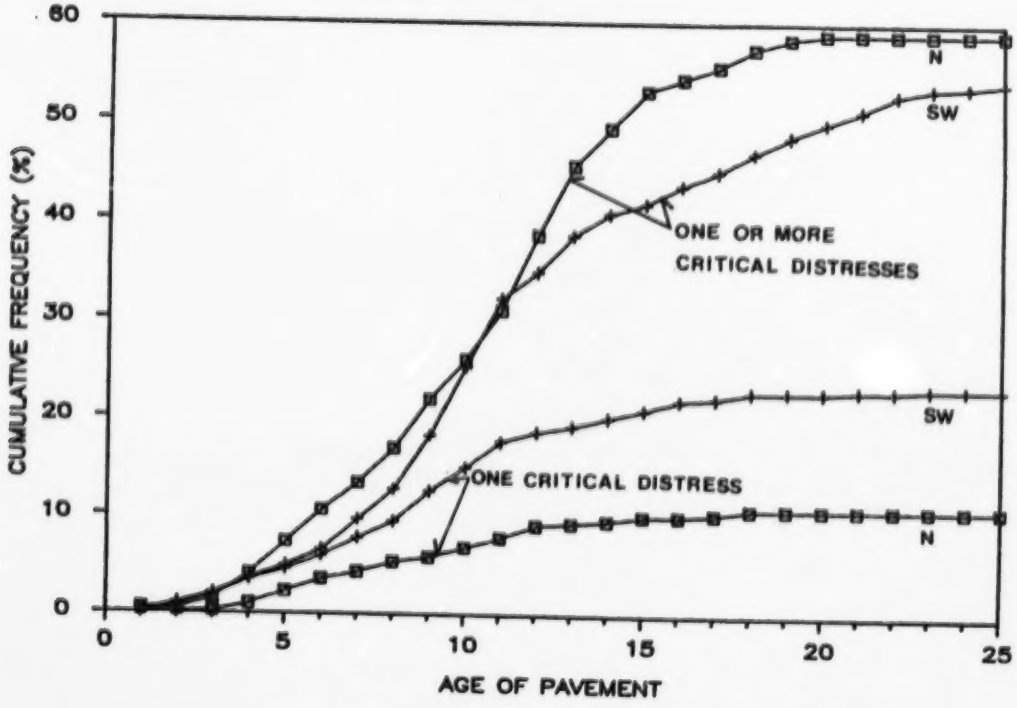

Figure 6/ Occurrence of Multiple Critical Distresses

Southwestern Region Northern Region